deployed at View Ridge Elementary, School (Seattle Public Schools) and in the adjacent residential neighborhood. Also, a CT-3 (TDMA) platform will be deployed at the Sheraton Seattle Hotel & Towers during this period. Technical and market surveys will be conducted for each platform.

SCI plans to begin CT-2 Plus platform deployment in February 1993 at the above-mentioned Seattle sites. SCI plans to include test and demonstration sites in Los Angeles, Long Beach and San Francisco. Once again, technical and market surveys will be conducted.

Full-scale testing of SCI's PCS SDMA system will begin in May 1993 with 200-users on a CT-2 Plus platform. System performance will be analyzed and problems solved as they are encountered. These tests will determine the system requirements for the final prototype design modifications prior to mass production and system installation. This phase of testing should be complete by September 1993.

Design release for production of PCS SDMA systems is expected by December 1993. The first PCS SDMA production units are expected to be available in the first quarter of 1994, and will be installed and brought on-line soon thereafter.

IV. IMPLEMENTING SDMA IN THE PCS ENVIRONMENT IS TECHNICALLY AND ECONOMICALLY FEASIBLE

A. Extensive Testing Conducted To Date Conclusively Demonstrates The Technical Feasibility of Implementing PCS SDMA

As fully demonstrated in Appendix A, and in Section III *supra*., SDMA PCS technology is at a level of development from which commercial implementation in the next two years is clearly feasible. A rigorous series of computer simulations and actual SDMA prototype system tests confirming the precise accuracy and flexible operation of SCI's SDMA technology, documented in Appendix A hereto, conclusively demonstrate the feasibility of PCS SDMA technology. Specifically, the ability of SCI's SDMA technology to spatially demultiplex co-channel signals on a dynamic real-time basis, and provide SNR at the output of the SDMA processor sufficient for accurate demodulation has been successfully demonstrated. In addition, the ability of SCI's SDMA technology to directionally transmit multiple co-channel signals to multiple receivers in a cell service area, with sufficient SNR at each receiver to permit successful demodulation of the intended signal is demonstrated in Section 5.1 and Figure 5.4 of Appendix A. Based on the foregoing, SCI submits that it has demonstrated the technical feasibility of its PCS SDMA technology, as required by Section 1.402(a) of the Commission's Rules.

B. PCS SDMA Implementation Is Economically Feasible and Will Yield Substantial Increases In PCS Profitability

Implementation of PCS SDMA is economically feasible, will yield substantial cost savings in system deployment costs, and increase the profitability of PCS systems. Section 6 of Appendix A, prepared by SCI's Chief Scientist and his staff, provides various cost factors relating to the implementation of PCS SDMA. The business planning staff of SCI has developed a proprietary model that augments the discussion of SDMA economics in Section 6 of Appendix A.

SCI's model uses the demographics of the central business district of Los Angeles, California PCS market ("LACBD") and quantifies the cost savings expected from reductions in the number of PCS base stations that will result from use of SDMA. SCI's model takes account of the SDMA implementation cost data provided in Appendix A, and incorporates SCI's estimates of PCS subscriber density and calling patterns. SCI uses grades of service and busy loading parameters typical in a wireline telephone system. SCI's selection of wireline telephone loading and service quality characteristics reflects SCI's belief that PCS will be required to meet wireline service quality and capacity in many market sectors. The model conservatively establishes a Grade of Service of .01, and a busy hour of 200 seconds per subscriber. SCI's assumptions associated with the model are as follows:

SCI Model Assumptions

• Busy Hour Seconds Per Subscriber:	200
• Grade of Service	.01
• Population Density/People per sq. mi.	13,948
• City Size	484.97 sq. mi.
• Coverage Area	100%
• Penetration*	5%
• Amount of Spectrum	25 MHz
• KHz per channel	100 KHz
• No of channels Per Base	6
• SDMA Multiplier	6
• Antennas Per Base Station	12
• Cost Per Base Station (CT-2 & CT-2 Plus, 6 RF Channel Capability)	
– Non SDMA	$2,500
– SDMA (12 antenna array)	$6,000

* Represents overall market penetration - the model accounts for relative increase in penetration due to PCS subscribers commuting to urban centers during the business day.

Using the above assumptions, SCI's model generated the following totals of serviceable subscribers per PCS base station for SDMA-equipped and Non-SDMA-equipped PCS cell sites.

Number of Subscribers Per Base Station

• CT2/CT2 Plus Non-SDMA	34
• CT2/CT2 Plus/SDMA	459

SCI's model generated the following estimates of total number of PCS base stations required to serve the LACBD.

Number of Base Stations Required

• CT2/CT2 Plus Non-SDMA	15,402
• CT2/CT2 Plus/SDMA	3,850

Based on SCI's estimates of PCS base stations and associated SDMA system costs (assuming use of an SDMA array at each base station capable of supporting six RF channels), the 75% reduction in the number of base stations required translates to a cost savings of $15.4 million if SDMA is used for deployment of PCS in the LACBD. The $15.4 million savings resulting from use of SDMA represents a 40% reduction in overall base station hardware costs for the LACBD.

Total Base Station Hardware Costs

• CT2/CT2 Plus Non-SDMA	$38,504,969
• CT2/CT2 Plus/SDMA	$23,102,981

Based on the foregoing, SCI submits that it has conclusively demonstrated that deployment of SDMA is not only economically feasible, but will result in substantial cost savings over conventional PCS deployment options and increase the profit potential of PCS operations.

V. IMPLEMENTATION OF PCS WITH SDMA TECHNOLOGY WILL SERVE THE PUBLIC INTEREST

SDMA-based PCS systems will realize a variety of compelling public interest objectives that have concerned the Commission since release of the PCS NOI, and PCS Policy Statement, supra. Chief among these goals are: no interference or disruption to existing microwave users; acceleration of PCS deployment; and increased PCS functionality and feature flexibility. SDMA's ability to realize these public interest objectives is discussed below:

No Interference to Existing Users-- The disruption and inefficiency attending relocation of existing microwave licensees or requiring these users to share assigned frequencies on a co-primary basis with PCS has concerned the Commission since it first considered PCS. As stated in the PCS NOI:

> As public safety entities, broadcasters, common carriers, utilities, and other important entities are using [the 1850-1990 MHz, 1990-2110 MHz, and 2110-2200 MHz] bands at present, we recognize that a reaccommodation of the microwave licensees in these bands could require a considerable amount of time and would likely preclude the implementation of PCN in certain areas for several years.[5]

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[5] 5 FCC Rcd at 3998 (para. 21). This sentiment was echoed in the PCS Policy Statement:

> Important equipment, cost and international considerations suggest that a portion of the spectrum

Initiating PCS with SDMA will resolve these concerns without detriment to incumbent licensees. As previously discussed, dynamic real-time spatial management of spectrum utilization is one of SDMA's most compelling features. This, in turn, eliminates inter-service frequency interference and will allow PCS and incumbent microwave licensees to operate co-channel in the same MSA or other geographical area.

Stated simply, initiating PCS with SDMA eliminates the spectrum allocation dilemma associated with introducing a new personal communications service. Assuming _arguendo_ that SDMA lacked its other well-known attributes-- _i.e._, spectral efficiency, service quality and design flexibility-- its singular ability to resolve the spectrum allocation dilemma satisfies a paramount public interest objective and should entitle SCI to grant of its instant request.

Accelerated PCS Deployment-- Another persuasive public interest attribute of SDMA derives from the one just discussed. As the Commission noted, relocating incumbent microwave licensees "would likely preclude the implementation of PCN in certain areas for several years." The geographic areas where incumbent

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> to be allocated should come from 1.8 to 2.2 GHz. We recognize that serious issues may exist for incumbents in this band and we intend to reallocate the spectrum needed for PCS _with minimum disruption to existing users_.

6 FCC Rcd at 6601 (para. 4) (emphasis added).

relocation will prove most difficult and time consuming are likely to be dense urban areas where PCS demand is anticipated to be most intense. Thus, the spectrum allocation problem will delay PCS availability in exactly those areas where it is needed most.

SDMA resolves this concern by allowing PCS and incumbent microwave users to co-exist in the same geographic area. As a result, the delay factor disappears as the daunting challenge acknowledged in the PCS NOI. By accelerating the advent of PCS, SDMA serves a second essential public interest objective.

PCS Functionality and Feature Flexibility-- Reflecting its intrinsic technological attributes, SDMA will allow an increase in functions and features that PCS systems can deliver to end users. By increasing channel capacity without additional (or at reduced) cost, SDMA will encourage PCS operators to provide a more enhanced menu of features and functions to the public. In addition, the SDMA technology will allow certain advanced services (e.g. position determination) to be provided with no significant increase in capital cost.

Increased Flexibility in PCS Licensing-- The spectral efficiencies resulting from SDMA will increase the effective capacity of PCS spectrum allocations. The availability of additional spectrum resource for PCS will allow the Commission to consider adoption of more than one PCS licensing scheme (e.g., two competitive common carrier operators and other private carrier services in the same service area).

VI. PROPOSED PCS LICENSING STRUCTURE AND POLICIES

SCI recommends that the Commission consider and adopt several basic rules to govern PCS licensing. Such rules should promote PCS's rapid introduction and availability, while capitalizing on lessons learned from the Commission's extended experience in regulating cellular communications. PCS's ability to deliver its multifaceted potential of versatile, affordable and convenient personal/mobile communications will surely depend on the underlying regulatory structure that is imposed on this exciting new service.

SCI respectfully submits that any scheme of regulation that promotes PCS's full potential will have the following characteristics:

- o geographic market structure resembling cellular;
- o eligibility restricted to promote competition and innovation;
- o licenses assigned on basis of comparative hearings, at least in 30 to 50 largest markets; and
- o extent of dislocation to existing users and spectral efficiency should be most significant comparative criteria.

These concepts are discussed in sequence below.

Market Structure-- Relying on the MSA/RSA geographic structure developed for cellular communications is advisable on several grounds. Most notably, MSA and RSA boundaries are already in place, and have proven effective in defining initial service areas for cellular operators. Nevertheless, these market definitions, in conjunction with Commission policy on assignments and transfers, have never inhibited consolidation of cellular systems into multi-market clusters and regional systems.

In addition to adopting cellular's geographical framework, the PCS regulatory framework should also utilize the two carrier per market concept. Spectrally efficient technologies like SDMA will enable the Commission to license two or more PCS carriers in a market; moreover, as already discussed, SDMA's substantial spectrum enhancement will give the Commission multiple options in its conceptual approach to PCS, e.g. licensing two PCS operators in a market as common carriers, and one or two co-market operators as private carriers (or vice-versa).

Promotion of Competition and Ownership Diversity-- The prospect of multiple licensees in individual MSA or RSA markets implies that PCS will be intensively competitive. Nascent rivalry among intramarket PCS carriers will be reinforced by the simultaneous availability in many areas of cellular and SMR, which are all generally regarded as close substitutes. As a result, consumers should have easy access to a diverse array of competing services, and their respective functions and features, at prices approaching cost. In terms of economic theory, this appears close to an optimal result.

SCI advises that promotion of materially enhanced competition and ownership diversity within the subject market should be a principal guiding policy in the issuance of PCS licenses.

Comparative Hearings-- The Commission recently indicated that comparative hearings may be the best method of selecting among mutually exclusive applicants, even for authorizations in the private land mobile service.[9] The Commission acknowledged that comparative hearings were "more exacting" than random selection and that unique characteristics of a particular service may make comparative procedures appropriate. Finally, the Commission noted that, notwithstanding adoption of measures specifically intended to prevent such a result, licensing of the 220-222 MHz band had been perceived as a "treasure hunt" by speculative applicants.

SCI submits that considering these factors in relation to PCS militates in favor of comparative hearings-- at least in the thirty to fifty largest MSAs where PCS demand is anticipated to be most intense and, as a result, where PCS licenses will be most valuable. The close functional connection between cellular and PCS virtually assures that a PCS lottery will attract a multitude of applicants whose principal intention is something other than public service. Accordingly, the Commission should utilize comparative hearings to award PCS authorizations in the largest MSAs.

Comparative Criteria-- Reflecting the foremost regulatory obstacle to PCS's establishment and ultimate development, SCI contends that two criteria should be dispositive in comparing mutually exclusive applicants. The first criterion should be the

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[9] Further Notice of Proposed Rulemaking in PR Docket No. 89-552 (Use of the 220-222 MHz Band By the Private Land Mobile Radio Services), FCC 92-27, released January 30, 1992.

extent of interference or disruption to existing licensees in the proposed frequency band(s) allocated for PCS. Applicants will be required to demonstrate quantitatively the extent to which existing users will experience interference or other service degradation by their proposed systems. Applicants proposing a technology (e.g. SDMA) that eliminates or substantially reduces this interference will be preferred because the technology will facilitate rapid availability of service.

The second criterion will be spectral efficiency. Increased efficiency implies lower capital and operating costs, making PCS a more affordable service other things being equal. At the same time, a spectrally efficient proposal increases the Commission's regulatory flexibility and creates spectrum for additional PCS allocations or other needed services. Accordingly, spectral efficiency should be the second comparative criterion.

VII. OTHER MATTERS RELATING TO SCI'S INSTANT REQUEST

As discussed fully in this Section, SCI's instant request is in full compliance with all Commission Rules. In fact, SCI submits that its foregoing demonstration of qualifications far exceeds the Commission's threshold showing requirement for grant of a Pioneer's Preference. For this reason, SCI should be awarded PCS licensing preferences in each of the three MSA markets where plans experimental tests and demonstrations.

A. SCI's Request Complies With All Commission Rules and Policies

The content requirements for a Pioneer's Preference Request, as set forth in Section 1.402 of the Commission's Rules are met or exceeded herein. In accordance with Commission Rules, the instant request demonstrates that implementing SCI's PCS SDMA technology is technically feasible.[9] In addition, SCI is unaware of any conflicts with existing Commission Rules that will result if the instant request for a PCS Pioneer's Preference is granted. For these reasons, SCI has met the Commission's regulatory requirements and is qualified for grant of a Pioneer's Preference.

B. No Petition for Rulemaking Is Required With This Pioneer's Preference Request

The integral relationship between SCI's PCS SDMA technology and the service and technical issues raised in General Docket No. 90-314 negates the need for SCI to accompany this Pioneer's

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[9] See Section 1.402(a) of the Commission's Rules. See also, Pioneer's Preference Order, 6 FCC Rcd at 3493, para 39; Pioneer's Preference Reconsideration Order, at paras 10-11. SCI also provides herein a detailed showing of the economic feasibility and attendant cost benefits that will accrue from its PCS SDMA technology. In support of this request, SCI reserves the right to submit, prior to release of a Notice of Proposed Rulemaking in General Docket No. 90-314, additional technical and economic data from SCI's PCS SDMA testing that are derived by SCI subsequent to the instant request's filing.

Preference request with a petition for rulemaking.[7] In General Docket No. 90-314, the Commission sought proposals for selecting PCS spectrum access techniques and appropriate technology applications to support use of these techniques by PCS systems.[8] The Commission also solicited proposals on methods for mitigating the impact on existing users that might result from establishing a primary PCS allocation.[9] SDMA's spectral efficiency and interservice compatibility enhancements respond directly and convincingly to these key issues in General Docket 90-314. Therefore, SCI need not file a petition for rulemaking here.

C. Area for Which Preference is Requested

Because of the sheer magnitude of the enhancements that SCI's SDMA technology will have on the implementation of PCS in the United States, SCI submits that it should be awarded a preference in the PCS licensing process for each of the MSA's where SCI's SDMA tests and demonstrations are planned. Accordingly, SCI provisionally requests that upon grant of SCI's Pioneer's

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[7] See Section 1.402(a) of the Commission's Rules. See also, Pioneer's Preference Reconsideration Order, FCC 92-57, at 8, para 19.

[8] See e.g., Notice of Inquiry in Gen Docket No. 90-314, 5 FCC Rcd 3995, 3999, para 29 (1990) ("PCS NOI"). See also, Policy Statement in Gen Docket No. 90-314, 6 FCC Rcd 6601, para 8 (1991) ("PCS Policy Statement"), at para 8.

[9] See PCS NOI, 5 FCC Rcd at 3997, para 19; PCS Policy Statement, 6 FCC Rcd 6601, at para 8.

Preference request, the Commission authorize SCI to construct and operate PCS systems serving the Los Angeles, California MSA, the Long Beach, California MSA, and the Seattle, Washington MSA. If the Commission determines that it is not possible to award SCI PCS licenses in each of the three designated MSAs, SCI hereby selects the Los Angeles MSA as an alternative choice. In the event the Commission does not adopt MSAs as a PCS service area definition, SCI reserves the right to designate an alternate service area(s) where its Pioneer's Preference shall apply.

VIII. CONCLUSION

SCI's pioneering role in the development and verification of proprietary PCS SDMA technology, in combination with the pivotal efforts of SCI, and its predecessors in interest, in the development of other key PCS technical and administrative components, renders SCI a prime candidate for award of a Pioneer's Preference in the Commission's PCS licensing proceeding. For the foregoing reasons, SCI respectfully submits that the Commission award SCI a Pioneer's Preference in the PCS licensing proceedings in General Docket No. 90-314. SCI provisionally requests that upon grant of SCI's Pioneer's Preference request, the Commission authorize SCI to construct and operate PCS systems serving the Los Angeles, California MSA, the Long Beach, California MSA, and the Seattle, Washington MSA. If the Commission determines that it is not possible to award SCI PCS licenses in each of the three designated MSAs, SCI hereby selects the Los Angeles MSA as an alternative choice. In the event the Commission does not adopt MSAs as a PCS service area definition, SCI reserves the right to designate an alternate service area(s) where its Pioneer's Preference shall apply.

Respectfully submitted,

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APPENDIX A

Appendix to Request of *Spatial Communications, Inc.* for a Pioneer's Preference in the Licensing Process for PERSONAL COMMUNICATION SERVICES

Implementing SDMA in the PCS Environment
Technical and Economic Factors

4 May 1992

Spatial Communications, Inc.

Appendix to Request of *Spatial Communications, Inc.*

for a

Pioneer's Preference in the Licensing Process

for

PERSONAL COMMUNICATION SERVICES

Spatial Communications, Inc.

4 May 1992

CONTENTS

1. Introduction

This document describes the application of a new technology to improving spectral efficiency and signal quality in Personal Communication Systems (PCSs). The technology employs *smart antennas* to separate signals not only based on their frequency content, but their spatial location as well. This Spatial Division Multiple Access (SDMA) technology is compatible with currently employed analog and digital signal modulation schemes including Frequency-Division Multiple Access (FDMA), Time-Division Multiple Access (TDMA), and Code-Division Multiple Access (CDMA), and can be used to increase the spectral efficiency (number of communication channels) and signal quality in all PCSs employing such schemes *without increasing the amount of allocated frequency spectrum.*

Many of the problems inherent in multi-user cellular-type wireless communication systems are a consequence of the omnidirectional nature of transmission of RF signals. While wide-area (omnidirectional) transmission is essential in current systems since the relative locations of the receivers and transmitters are not known, it *pollutes* the electromagnetic environment by radiating most of the total transmitted power in directions other than *toward* the intended receiver. This leads directly to (cochannel) interference problems which severely limit the overall system capacity and quality.

The fundamental concept involved in SDMA is exploitation of the spatial dimension in a heretofore unthought of manner in wireless (mobile) communication networks. By using more than one receiving antenna, *i.e.*, an array of simple antennas, and *spatially* sampling the electromagnetic fields, it is possible to estimate the directions-of-arrival (DOAs) of multiple cochannel signals and to *separate* the underlying source waveforms. By using multiple transmit antennas, energy can then be selectively directed toward the intended receivers without interfering with other users and keeping RF pollution to a minimum. Since multiple users are allowed to occupy the same (frequency or code) channel at the same time, spectral efficiency is greatly enhanced, and by spatially selectively transmitting RF energy, RF pollution and hence interference is greatly reduced. This also increases spectral efficiency by increasing the capacity of each communication link, a consequence of reducing the overall system noise/interference level. Furthermore, SDMA's multiple receive antennas provide gain at the output of the SDMA processor, gain which can be used to reduce the power of the transmitters at the other end of the link, thus increasing the talk-time of portable mobile units. Though similar in structure to phased-arrays, the signal processing performed in the SDMA system is state-of-the-art technology, the real-time implementation of which has only recently been made feasible with the advent of high-speed special purpose digital signal processing hardware.

2. The SDMA Concept

Wireless communication systems are generally composed of one or more local central sites, herein termed *base stations*, through which wireless transmitter/receivers gain access to a larger information network. Base stations service *local* areas wherein a number of wireless users, fixed or mobile, are located. The function of the base station is to relay messages to and from users all over the network. In cellular mobile systems, for example, this task is performed by relaying messages to and receiving signals from a Mobile Telephone Switching Office (MTSO). A wireless user establishes a two-way (full-duplex) communication link with one or more other users also having some access to the network by first requesting access to the network through the local base station. This communication is accomplished in cellular mobile communications and wireless local area computer networks (LANs), for example, by suitably modulating electromagnetic waves. The same is true of the next generation Personal Communication Systems (PCSs) to which this document is directed.

Current state-of-the-art requires that users transmit signals in different frequency channels, use different coding schemes in the same frequency channels, or be transmitted in non-overlapping time intervals for the signals to be correctly received. SDMA is a new technique for separating multiple messages in the same frequency, code, or time channel using the fact that they are in different *spatial* channels. Hereinafter, the term *channel* will be used to denote any of the conventional channels (frequency, time, code) or any combination thereof. The term *spatial channel* refers to the new concept unique to SDMA.

Wireless communication is becoming an increasingly common form of communication, and the demand for such service continues to grow. Examples in operation today include cellular mobile communication networks, wireless telephone networks, cordless telephones, satellite communication networks, wireless cable TV, multi-user paging systems, high-frequency (HF) modems, and more. The next generation PCS systems will be yet another addition to this list. Current implementations of these communication systems are all confined to limited frequency bands of operation either by practical considerations or, as is more often the case, by government regulation. As the capacity of these systems has been reached, demand for more service has had to be met by allocating more frequency spectrum to the particular application along with attempts to utilize the allocated spectrum more efficiently. In light of the basic physical principle that transmission of information requires bandwidth, the fundamental limitations of a finite amount of practically usable spectrum present a substantial barrier to meeting an exponentially increasing demand for wireless information transmission. Since, as has been demonstrated over the last decade, the amount of practically usable frequency spectrum can not keep pace with the demand, there is a critical need for new technology for increasing the ability of such systems to transfer information. This document directly addresses this need and describes proprietary Spatial Communications, Inc. technology which is compatible with current as well as future modulation schemes and standards.

2.1 Review of Current Technology

In current state-of-the-art, a base station serves many channels by means of different multiple access schemes, the most common being Frequency-Division Multiple Access (FDMA), Time-Division Multiple Access (TDMA), and more recently Code-Division Multiple Access (CDMA). All current systems employ FDMA wherein the available frequency bandwidth is sliced into multiple frequency channels and signals are transmitted simultaneously, with a maximum of one per channel at any given time. All wireless systems also currently employ a form of TDMA, a technique wherein multiple users share a common frequency channel by doing so at different times, in that when a user no longer requires the channel assigned to it. the channel is reassigned to another user.

2.1.1 TDMA

In the more common meaning of the term, TDMA is also being exploited on a more fine grain level, an example of which is the implementation of the IS-54 domestic digital cellular system (D. Goodman, "Trends in Cellular and Cordless Communications," *IEEE Communications Magazine*, June 1991). Analog data, such as voice, is digitized, compressed, then sent in bursts over an assigned frequency channel in assigned *time slots*. By interleaving multiple users in the available time slots, increases in the capacity (*i.e.*, number of simultaneous users) of the system can be achieved. At its maximum, the IS-54 standard provides for a factor of 6 increase over the current 30 *KHz* analog (AMPS) standard by packing 6 voice channels into a single TDMA *frame*. However, initial implementations provide for a factor of 3 increase only. TDMA requires substantial modifications to the base station receiver hardware as well as the mobile units themselves, since current analog units are not capable of exploiting this technology. Consequently, a dual-mode standard, supporting both the new digital and the old analog transmission schemes, has had to be adopted.

2.1.2 CDMA

CDMA allows multiple users to share a common frequency channel by using coded modulation schemes. The technology involves preprocessing the signal to be transmitted by digitizing it, modulating a *wideband* coded pulse train, and transmitting the modulated coded sign .. in the assigned channel. Multiple users are given distinct codes which decoders in the receivers are programmed to detect. If properly designed, the number of simultaneous users of such a system can be increased over the current state-of-the-art. Proposed systems indicate a potential factor of 10 improvement in spectral efficiency. The SDMA concept described herein can be applied directly to further increase capacity and system performance of CDMA systems by dynamic sector assignment. Practically, increases by factors from four (4) to ten (10) over omnidirectional schemes are achievable with SDMA.

The aforementioned techniques represent various attempts to more efficiently *pack* an increasing number of signals into fixed-width frequency channels. These techniques do not exploit the *spatial* dimension when establishing channels. Common to all the aforementioned systems is essentially omnidirectional (possibly wide-area sectorized) transmission of RF energy in an attempt to establish point-to-point communication links. This turns out to be a reasonable strategy in current systems since the relative locations of the mobile units are not known. It does, however, suffer from an extreme inefficiency in that the ratio of useful power (power actually received by the mobile unit) to the total power transmitted is extremely small. As a consequence, most of the transmitted power from both the base stations and the mobile units is actually interference to the remainder of the system. This RF *pollution* prevents multiple users from sharing the same frequency channel within local areas comprising many cells in all but CDMA transmission schemes where using coding and power control users are allowed to use the same channel.

This document describes how, *in addition* to traditional schemes, the spatial dimension can be exploited to:

1. significantly increase the number of channels that a base station can serve without allocation of more frequency channels,

2. significantly increase the quality of the communication links,

3. significantly reduce the required amount of transmitted power from both the base stations and the mobile units,

4. lower the overall system deployment cost by reducing the number of base stations required to handle a given system load,

5. significantly increase flexibility in system architecture permitting more efficient system deployment,

6. *allow for coexistence with current (e.g., point-to-point) users of the same spectrum!*

This proprietary technology is hereafter referred to as Spatial-Division Multiple Access (SDMA).

2.2 Current Methods for Increasing Capacity and Quality

2.2.1 Microcells

Heretofore, to increase the capacity of cellular systems, the area covered by each base station is reduced, increasing the number of cell sites required to cover a given area, but allowing more users to access the system. The idea is that signals *far enough away* will not interfere with local sources since power dissipates quite rapidly in space the further from the transmitter the receiver is located. This straightforward approach to increasing capacity is often referred to as the *microcellular* concept, and is the currently favored concept for handling anticipated demand in the coming PCSs. SDMA is entirely compatible with the microcellular approach to PCS deployment and in fact will further improve the spectral efficiency, yield an improvement in signal quality, and help to increase the accuracy and reliability of hand-offs.

2.2.2 Sectorization

Sectorization is a currently employed technique in cellular systems for increasing signal quality by dividing up the area served by a base station into sectors. Rather than transmitting omnidirectionally, antennas which transmit the majority of their power in sectors of fixed angular extent (*e.g.*, 120° in a 3-sector system) are used. Multiple fixed antennas cover the entire cell. The advantage of this technique is that by restricting the field of view, the number of cells potentially interfered with is reduced. Since there is insufficient isolation between sectors, channels are not reused in the various sectors in a cell. As a result, capacity is not increased. Thus, fixed sectors can be thought of as simply another technique for reducing the size of the cells in the system to reduce cochannel interference without increasing capacity. Though certainly not a precise statement, SDMA can be viewed as essentially a dynamic (smart) sectorization technique in which the sectors (loosely speaking) *track transmissions from mobile wireless units* and direct energy thereto. However, unlike fixed sectorization schemes, an increase in capacity of the system results as well.

2.3 Cochannel Interference

In current systems, it is assumed that there is only one mobile unit at a time transmitting in a given cell on a given channel. These channels can be frequency channels as